MHD Simulation of the Plasma Flow in the Magnetic Nozzle

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The magnetohydrodynamic (MHD) flow of plasma through a magnetic nozzle is simulated utilizing cross-sectional geometries of the magnetic coils that make up the magnetic nozzle. This is in order to numerically investigate the flow and behavior of the plasma for different variables, such as locations going past the coil, at different Mach numbers, and different magnetic fields. The MHD simulations are useful for addressing issues such as the plasma detachment problem and to gain insight into the physical processes of experimental thrusters.

MHD equations for a multi-fluid plasma, containing both electrons and ions, are integrated over a finite cell volume which is broken into 6 faces with flux going through each face [1]. Typically, MHD equations are written in mathematically conservative, differential forms. Stokes theorem is used to convert the area integrals over the faces of each cell into line integrals around the boundaries of each face. The states of the plasma, such as ionization, equation of state, thermal conductivity, and resistivity, are represented as well as anisotropies in current conduction due to Hall effect.

A magnetostatic solver provides the initial conditions for the applied magnetic field, which are applied with other initial conditions to develop the flow patterns that occur in the downstream portions of the magnetic nozzle. The magnetic coils are represented cross-sectionally with corners, as seen in Figure 1 [2]. This previous research was able to demonstrate effects such as back-emf at a super-Alfvenic flow, which significantly alters the shape of the magnetic field.

However, corners in the geometry cause the code to generate numerically unstable data. Counter-rotating currents are present under the coil, and they are not present in simulations of free expansion downstream of the coil. This issue may be addressed by modifying the geometries of the cross section to be cone-shaped instead of square-shaped, flaring out at the end of the coil. Previous research on modeling the nozzle geometries as an infinite cone were performed by the VASIMR group [3].

References

[1] K. Sankaran and K. Polzin, “Development of Numerical Tools for the Investigation of Plasma Detachment from Magnetic Nozzles,” *38th AIAA Plasma Dynamics and Lasers Conference,* Miami, FL, June 2007

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[3] A. Arefiev and B. Breizman, “Magnetohydrodnamic Scenario of Plasma Detachment in a Magnetic Nozzle,” *Physics of Plasmas* **12**, 043504-1 (2005)

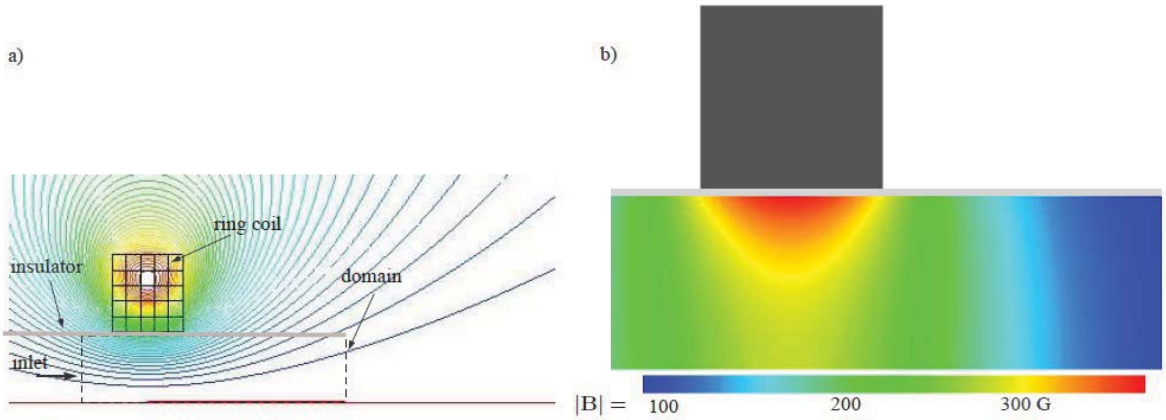

Figure 1. a) Schematic of the experimental setup and the domain that was modeled in this paper. Magnetostatic simulation results showing the magnetic flux lines in the $r - z$ plane of the nozzle are presented, with these data used as the applied field background in this simulation; b) Magnitude of the applied magnetic field produced by the coil.